Name of the file:	Tokkyogan (Patent application)
File number:	DXX03-022
Application date:	November 4, Heisei 15 (2003)
Address:	Patent Office Head
International patent file:	HO1L 23/36

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Ledger number for payment before application:
014395

Amount of money: 21,000 yen

Catalogue of application article:

Name of article: Scope of the Patent Application: 1

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Total power of attorney number: 0012334

Name of file: Scope of the patent application

Application Item 1:

Heat conducting material with the following features: onto No. 1 graphite sheet that has high heat conducting characteristics, number 2 and number 3 graphite sheets are laminated, and these number 2 and 3 graphite sheets have higher isotropic heat conductive characteristics than the No. 1 graphite sheet.

Application Item 2:

The heat conducting material described in Application Item 1 has compression rate of compressive thickness 8-40%.

Application Item 3:

Heat conducting material of Application Items 1 & 2 with the following features: the average heat temperature difference Δt (K) between two points between the No.1 sheet and number 3 sheet that are laminated, the thickness of the No.1 sheet before compression C (mm), the thickness of the number 2 sheet before compression M1 (mm), the thickness of the number 3 sheet before compression M2 (mm), and the heat resistance W (K· cm^2/W) of the No.1 sheet and the third sheet will satisfy the following formula:

$$\Delta t \le 3/5\,(\sin^2(2C/(M1+M2))\cdot W-2.5)^2 + 1.5$$

$$(0<\sin^2(2C/(M1+M2))\,W \le 8)$$

Application Item 4

Heat conducting material in either Application Item 1 or 3 with the characteristic that the surface direction heat conduction rate of previously mentioned No.1 sheet is higher than 100W/m · K before it is compressed.

Application Item 5:

The heat conducting material in either the Application Item 2 or 3 with the characteristic of heat conduction rate is over 60W/m · K, and also the specific heat capacity of the heat conduction material of either Application Item 1 or 4 is more than twice that of the No.1 sheet specific heat capacity.

Application Item 6:

The heat conducting material in either Application 1 or 5 has characteristic that the No.2 or 3 sheet is made of either metal or ceramics.

Name of the file: Details
Name of the invention: Heat conduction material
Technical field:
0001:
This invention concerns a heat conduction material that is used to cool various electronic devices, such as semiconductor elements.
0002:
Electronic devices such as notebook personal computers, PDA (Personal Digital Assistants), cell phones, digital cameras, digital videos etc. have rapidly accelerating speed of function and processing capability. Consequently, the heat generated by semiconductor elements and other electronic parts that are used for CPU etc. are increasing. Therefore, effective cooling and heating systems are required in order to have motion characteristics and reliability of semiconductor elements.
0003:
In electronic devices that have high heat semiconductor elements, there are various types of cooling and heating systems. Typical of those are, cooling by attaching a cooling fan, cooling fin, Peltier element (cooling element), etc. to the electronic device itself, or exhausting heat inside the device by attaching an exhaust fan to the device itself. However, for portable electronic devices, it is difficult to attach a cooling fan or fin to the device itself because of the small space. Also a semiconductor element can not be cooled effectively only by an exhaust fan using the heat generated inside the electronic device body.
0004:
Therefore, materials which tend to get hot, such as semiconductor elements, etc. inside the electronic device and an exhaust device such as exhaust fan or fin attached outside the wall of the electronic device are connected, using heat conducting material such as heating pipe in order to save space for the heating system, and emphasize effectiveness of cooling the semiconductor element. This method is already is used partially (for instance, see Tokkyo reference 1, 2). Moreover, use of graphite sheet is considered (refer to Tokkyo reference 2, 3.).
0005:
But, since heat pipe is not only heavy but also it has difficulty because of bending shape; for that reason, it is difficult to install inside a portable electronic device. On the other hand, graphite sheet is an excellent heat conducting material, because its heat dispersion characteristic is good, light in weight, space limitation is small; it disperses the heat quickly generated by portable electronic devices that are getting smaller and smaller.
0006:
However, the amount of heat from semiconductor element etc. is considered to increase as semiconductor technology develops. Also we think that requirement increases for smaller and lighter electronic device with high heat element. For these reasons, development of heat conducting material that has effective exhaustion of heat while having characteristics of graphite sheet such as light and space-saving, are sought after strongly.

(Tokkyo reference) Tokkai-Hei8-204373 Open Journal
(Tokkyo reference) Tokkai2000-82888 Open Journal
(Tokkyo reference) Tokkai2003-188323 Open Journal

0007:

The purpose of this invention is to answer those demands; it is to offer a heat conducting material that it is light, saves space, can relay heat effectively from a heating body to an exhaust system so that it can meet the requirement of a larger quantity of heat in a smaller size of electronic device.

Procedure to solve the problems

0008:

In order to achieve the above-mentioned purpose, the heat conducting body mentioned in Application Item No.1 of this application has the following characteristics: on to main graphite that has high heat conduction characteristics on both sides, Nos. 2 & 3 sheets that have higher isotropic heat conducting material are laminated.

0009:

The characteristic of the invention mentioned in Application Item 2 is a heat conducting material that has 8-40% compression pressure rate of pressured lamination.

0010:

The characteristic of the invention mentioned in Application Item 3 is the following: in the heat conducting material of Application Items 1 & 2, the average heat temperature difference Δt (K) between two points in either the No.1 sheet or the No. 3 sheet that are laminated, the thickness of the No.1 sheet before compression C (mm), the thickness of the No. 2 sheet before compression M1 (mm), the thickness of the No. 3 sheet before compression M2 (mm), and the heat resistance W ($K \cdot cm^2/W$) of the No.1 sheet or the No. 3 sheet satisfy the following formula:

$$\Delta t \leq 3/5(\sin^2 (2C/ (M1+M2)) W-2.5)^2 + 1.5$$

$$(0<\sin^2 (2C/ (M1+M2)) W \leq 8)$$

0011:

In the detail of this invention, the average temperature difference Δt between two points is, as shown in the drawing 10, the average temperature difference between two points, P, Q or P, R on the lower surface of laminated sheet 11, when a chip type heating body 12 (contacting size: 1cm x 1cm, heating value: 10W) touches the upper side of sheet 11. Point P is a point on the edge of a multiple facets square of the heating material 12: when two of the edges are extended, they cross at Point P: point Q and R are the points on these lines and they are located 5cm away from the Point P.

The heat resistance W is measured by the parallel flat sheet method.

0012:

The invention described in Application Item 4 has the characteristic that the heat conducting material in either Application Item 1 or 3, the No.1 sheet, the surface direction heat conduction rate before the No. 1 sheet is pressed, is over 100W/m·K.

0013:

The invention described in Application Item 5 is, that the heat conducting material described in either the Application Item No. 1 or 4, No.2 and 3 sheets have over 60W/m · K heat conducting rate; at the same time, the specific heat capacity is twice as large as the No.1 sheet.

0014:
The invention described in Application Item No. 6 is, for the heat conducting material described in either Application Item No. 2 or 3, No.2 & 3 sheets are made of either metal or ceramics.

Effect of the invention
0015:
According to this invention, [it is] lighter and excellent to save space, while we obtain a better heat conduction body with more effective heat conduction rate from the heating body to the exhaust system than before; consequently the heat generated by a semi-conducting element etc. can be treated in a smaller package.
0016:
I will explain the actual format of this invention in the following pages.
0017:
Drawing 1 is an overall squint eye view of the actual form.
In drawing 1, 21 is the No.1 sheet made of graphite that has high heat conduction: on both sides of the No.1 sheet 21, sheet Nos. 2 & 3, 22, 23 that are made of larger isotropic heat conducting material with larger specific heat capacity than the No.1 sheet 21 are laminated and pressed as one sheet. The purpose of pressurizing is to increase the surface direction heat conduction and heat dispersion characteristics for the entire heat conducting material 20.

0018:
Graphite that construct No. 1 sheet 21 is made of so called lamination construction which means that graphite crystals are laminated toward surface direction: because of this construction, it has aelotropic heat conduction, and the surface direction (layer direction) heat conducting rate is 100W/m · K or even higher than 200/m· K. In order to get this high effect, the thickness of the graphite sheet (before pressure) should be 0.03-10mm or 0.25-2mm is better.
0019:
This type of graphite sheet can be made by pressuring flake type graphite with a rolling roller or press mold machinery: or flake graphite can be molded by an extruding mold or it can be made even using pressurizing mold or an extruding mold as amorphous carbide is heated. Also, for instance, you can make it by heating a macro-molecular film, like aromatic poly-imido [?] film, at several thousand degree temperature in inert gas atmosphere.
0020:
The material of No. 2 or 3 sheet, 22, 23 made of isotropic heat conducting material, is not limited to certain materials as long as the specific heat capacity is larger than that of No.1 sheet 21. However, it is preferred that the heat conducting rate be over 60W/m · K and the specific heat capacity be twice as large as that of No. 1 sheet, in order to control lowering of heat conduction rate by increase of heat resistance so as to increase the surface direction heat conducting and heat dispersion rates of No.1 sheet 21.
0021:
Actually, a sheet that is made of metal material such as aluminum or copper is used. Also high heat conducting ceramic, for instance Aluminum Nitride (AlN), Silicon Carbide (S i C), Alumina (Al_2O_3), Boric Acid Nitride (BN), Silicon Nitride (SiN), or Zircon (ZrO_2). Those

materials can be used as supporting material for No. 2 and 3 graphite sheet 22, 23. Also when a metal such as aluminum or copper is used, molding capability of graphite sheet can be: on the other hand, when ceramics are used, it can insulate electricity from graphite sheet surface.

0022:

Thickness (before pressure) of sheet made of isotropic heat conducting material is preferably 0.02-20mm and 0.02-1mm.

0023:

Heat conducting material 20 of this actual form, for instance as it's shown in drawing 2, can be manufactured by, first, No 2 sheet 22 and No. 3 sheet 23 are compressed onto both sides of No. 1 sheet 21 using glue 24, then apply pressure to this laminated body in the thickness direction with a rolling roller etc. As for the material of glue 24, cellulose type, acryl type, silicone type, Epoxy type or urethane type glue can be used. Or, without using such glue, it can be pressurized into one sheet through lamination of No. 1 sheet 21 and No. 2 sheet 23, using material that has melting characteristic between the sheets when they are pressurized.

0024:

Pressurizing is preferred to have more than 8% pressurizing rate as shown below; if the pressurizing rate is below 8%, the heat conducting characteristics can not be used fully. 10-40% pressurizing rate is even better.

Pressurizing rate (%) = [(thickness of laminated body before pressure – thickness of laminated body after pressure)/ laminate thickness before pressure] x 100

0025:

Heat conducting material 20 of this actual form should be light, and because (No. 1 sheet is laminated to) No. 2 sheet and No. 3 sheet 22, 23 made of bigger specific heat capacity isotropic heat conducting material than No. 1 sheet, heat conducting characteristic of No. 1 sheet can be improved to much higher capacity, consequently it can conduct heat from the heating body to the exhause system much more effectively.

0026:

The reason that the heat conducting characteristic of No. 1 sheet 21 made of graphite improved so much is, by arranging No. 2 & No. 3 sheet 22, 23 made of isotropic heat conducting material, excellent bilateral heat conducting characteristic of graphite sheet is used, and in addition to that, interaction between the heating characteristics of a graphite sheet and heating characteristic of a sheet made of isotropic heat conducting material increases the surface direction heat conducting characteristic of graphite sheet even more.

0027:

In this invention, in the above mentioned heat conducting material 20 actual form, average heat difference Δt (K) between two points 22, 23 of pressured sheet No. 1 or 3 sheet 21, thickness before being pressurized C (mm) of No. 1 sheet 21, thickness before pressurized M1 (mm) of No.2 sheet 22, thickness before pressurized M2 (mm) of No. 3 sheet 23, and heat resistance W ($K \cdot cm^2/W$), should satisfy the formula below; when it is satisfied, not only the heat conducting characteristic but it can have other characteristics (camber, anti separation, light weight) also.

$$\Delta t \leq 3/5\,(\sin^2(2C/(M1+M2))\,W-2.5)^2 + 1.5$$

$$(0 \leq \sin^2(2C/(M1+M2)) \cdot W \leq 8)$$

0028:

In an actual test case, we prepared graphite sheets (specific heat capacity 0.13J/K·g, specific gravity 1.78gcm^3, surface direction heat conducting rate 240W/m·K) in different thickness for No. 1, sheet 21: also we prepared copper sheets (specific heat capacity 0.38/K·g, specific gravity 8.96g/cm^3, heat conducting rate 390W/m·K) in different thickness for No. 2 and 3 sheet 22, 23, and by mixing different sizes, according to the procedure shown on Drawing 2, we produced the heat conducting material of construction shown on Drawing 1. Cellulose was used for glue 24, and the pressuring rate of lamination thickness was 10% in each case.

0029:

The heat conducting material thus produced was considered to be good in actual consummation, after we measured the heat resistance W and the average temperature Δt difference between two points, and investigated the camber and separation occurrences. The result is in Table 1, and on the basis of the result, when we use $\sin^2 (2C/(M1+M2))\cdot W$ as the horizontal axis, and Δt as the vertical axis, we confirmed that it is within fairly good condition which satisfy the above-mentioned formula, as shown on Drawing 3.

0030:

Table 1

1. Thickness of graphite sheet (mm)
2. Copper sheet (mm)
3. Evaluation
4. Good

0031:

Moreover, a similar test was performed on an aluminum sheet (specific heat capacity 0.27J/K·g, specific gravity 2.24g/cm^3, heat conducting rate 220W/m·K) and aluminum nitride sheet (specific heat capacity 0.8J/K·g, specific gravity 2.0g/cm^3, heat conducting rate 170W/m·K), almost same result was observed, even though the materials were different.

0032:

Heat conducting material 20 in this actual form can be made into various forms as they are shown in drawings 4-8. In drawing 4, heat conducting material 20 is cut in a certain shape and size, and the heating side of body 31 such as semiconductor element is attached on the main surface of one side, and an exhaust fin as heat exhaust is attached at the other side of the main surface. In the example shown in drawing 5, both heating body 31 and heat exhaust system 33 are attached on one side of the main surface of heat conducting material 20. Also in the example shown in drawing 6, three-dimensional shape is added by attaching heating body 31 and box 34 which is also a heat exhaust system of an electronic device together: similarly in drawing 7, heat conducting material is made in a three-dimensional shape because the heating body 31 and the

exhaust sheet 35 are connected by heat. And finally in drawing 8, the heat conducting material 20 can be used as the heat exhaust sheet as well.

0033:

When heat conducting material 20 was simply cut, No. 1 sheet made of graphite was exposed at the edge, and it might cause some dust, therefore it is preferable to use cover 25 on the surface using the before-mentioned glue etc., as shown in drawing 9.

Examples

0034:

I am going to show some examples according to this invention, but the invention is not limited to the following examples.

0035:

Example 1-3

On both surfaces of the graphite sheet (specific heat capacity 0.13J/K·g, specific gravity 1.78g/cm3, heat conducting rate on both direction 240W/m·K) that is 1.5mm thick, 60mm wide, and 150mm long, a copper sheet (specific heat gravity 0.38J/K·g, specific gravity 8.96/cm3, heat conducting rate 390W/m·K) that is 0.5mm thickness, 60mm wide, 150mm long, are laminated using cellulose type glue and pressed, thus heat conducting material of pressured rate 10%, 20% and 30% are made.

0036:

About the made heat conducting material, heat resistance W and average temperature difference Δ t between two points are measured. Table 2 is showing both results of the tests when it is conducted with pressure rate is 0% (Comparison Sample 1) and at the time only a graphite sheet is used.

Table 2

1. Composition
2. Pressure rate (%)
3. Heat resistance W (Kcm^2/W)
4. Average temperature between 2 point Δt (K)
5. Sample 1
6. Copper/graphite/copper
7. Sample 2
8. Copper graphite/copper
9. Sample 3
10. Copper/graphite/copper
11. Comparison sample 1
12. Copper/graphite/copper 5
13. Comparison sample 2
14. Graphite

0037

Sample 4-6

On both sides of a graphite sheet (specific heat capacity 0.13J/K·g, specific gravity 1.78g/cm^3, heat conduction rate in both directions 240W/m·K) that is 1.45mm thick, 60mm wide, and 150mm long, an aluminum sheet (specific heat capacity 0.27J/K·g, specific gravity 2.24g/cm^3, heat conduction rate 220W/m·K) that is 0.1mm thick, 60mm side, 150mm long was laminated

and pressed using cellulose type glue, thus heat conducting material with pressurizing rates of 13%, 19% and 27% were made.

0038:

Heat resistance W and average temperature difference between two points Δ t were measured about the heat conducting body made (in sample 4-6). The results are shown in Table 3. There are three different test results shown on the Table 3: the result when an aluminum sheet was laminated only on one side of the graphite sheet (Comparison Sample 3), the result when it is constructed only with graphite sheet (Comparison Sample 4), and the result when pressure rate was 40% (Comparison Sample 5).

Table 3

1. Construction
2. Pressure rate (%)
3. Average temperature difference Δt (K)
4. Sample 4
5. Aluminum/graphite/aluminum
6. Sample 5
7. Aluminum/graphite/aluminum
8. Sample 6
9. Aluminum/graphite/aluminum
10. Comparison sample 3
11. Aluminum/graphite
12. Comparison sample 4
13. Graphite
14. Comparison sample 5
15. Aluminum/graphite/aluminum
16. Broke when it was pressed.

As it is shown in Table 2 & 3, the heat conducting material of this invention had better results when they are compared with other cases in comparison samples.

Simple explanation of the drawings

0039

Drawing 1: squint view of actual form of the heat conducting material of this invention.

Drawing 2: cross section of one example of manufacturing procedure of this heat conducting material shown in Drawing 1.

Drawing 3: drawing that shows construction and characteristic of the heat conducting material of this invention.

Drawing 4: side view that shows one example of using the form of the heat conducting material of this invention.

Drawing 5: side view that show other example of using form of the heat conducting material of this invention.

Drawing 6: side view that shows another example of using form of the heat conducting material of this invention.

Drawing 7: side view that shows another example of using form of the heat conducting material of this invention.
Drawing 8: side view that shows another example of using form of the heat conducting material of this invention.
Drawing 9: cross section that shows a different example of the actual form that is shown in drawing 1.
Drawing 10: squint view of explanation how to measure average temperature difference Δt between two points.
Explanation of signs:
0040:
20: heat conducting material, 21: No. 1 sheet made of graphite, 23: No. 2 sheet made of isotropic heat conducting material, 24: glue, 25: cover, 31: heating body, 32: heat exhaust fin, 33: heat exhaust system, 34: box, 35: heat exhaust sheet.

Name of the file: Summary
Summary
Purpose of the invention: To offer heat conducting material which is light, saves space, and heat conduction from heat source to heat exhaust system can be done effectively
How to solve: Heat conducting material with the following features: onto a main graphite sheet 21 that has high heat conducting characteristics, number 2 and number 3 graphite sheets are laminated, and these number 2 and 3 graphite sheets 22, 23 have higher isotropic heat conduction characteristics than the main graphite sheet 21.
Selected drawing: Drawing 1.